FISHERY DATA SERIES NO. 97

STOCK STATUS OF CHENA RIVER ARCTIC GRAYLING[1]

By

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ABSTRACT

Arctic grayling *Thymallus arcticus* were captured by pulsed direct-current electrofishing in two sections of the lower 152 kilometers of the Chena River in 1988. Stock status of Chena River Arctic grayling was described by population abundance, age composition, size composition, growth, recruitment, and survival estimates. Estimated population abundance in the lower 72 kilometers of the Chena River (Lower Chena section) was 7,760 Arctic grayling greater than 149 millimeter fork length; and was 14,444 Arctic grayling greater than 149 millimeter fork length in the upper 80 kilometers of the Chena River (Upper Chena section). Age 5 Arctic grayling were strongly represented in both sections of the Chena River, while size composition varied among river sections. Growth of Chena River Arctic grayling was successfully modelled with the von Bertalanffy growth equation. Annual recruitment between 1986 and 1987 was 2,526 Arctic grayling and annual survival during this period was 43.9 percent. Annual recruitment increased to 3,373 Arctic grayling between 1987 and 1988, with an increase in annual survival to 57.1 percent. All stock status indicators were estimated with high precision, although estimated annual survival between 1986 and 1987 was imprecise. Imprecision of the survival estimate was due to imprecision of the 1986 abundance estimate.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, electrofishing, population abundance, age composition, size composition, Relative Stock Density, growth, recruitment, survival rate, Chena River.

Table 1. Summary of total angling effort and Arctic grayling harvest on the Chena River, 1977-1987[1].

Year	Lower Chena River[2]		Upper Chena River[3]		Entire Chena River	
	Angler-days	Harvest	Angler-days	Harvest	Angler-days	Harvest
1977[4]	---	---	---	---	30,003	21,723
1978[4]	---	---	---	---	38,341	33,330
1979	9,430	11,290	8,016	11,664	17,446	22,954
1980	13,850	18,520	10,734	16,588	24,584	35,108
1981	11,763	10,814	10,740	13,735	22,503	24,549
1982	18,818	11,117	15,166	12,907	33,984	24,024
1983	17,568	7,894	16,725	10,835	34,293	18,729
1984	20,556	13,850	11,741	12,630	32,297	26,480
1985	11,169	2,923	8,568	3,317	19,737	6,240
1986	18,669	4,167	10,688	3,695	29,357	7,862
1987	12,605	1,230	10,667	1,451	23,272	2,681
Averages[5]	14,936	9,089	11,449	9,647	26,386	18,736

[1] Taken from Mills 1979-1988.
[2] Lower Chena River is from the mouth upstream to 40 km Chena Hot Springs Road (Mills (1987).
[3] Upper Chena River is the Chena River and tributaries accessed from the Chena Hot Springs Road beyond 40 km on the road (Mills 1987).
[4] Angler-days and harvest are computed for the Chena River and Badger Slough.
[5] Averages are for 1979 through 1987 only.

Harvest of Arctic grayling
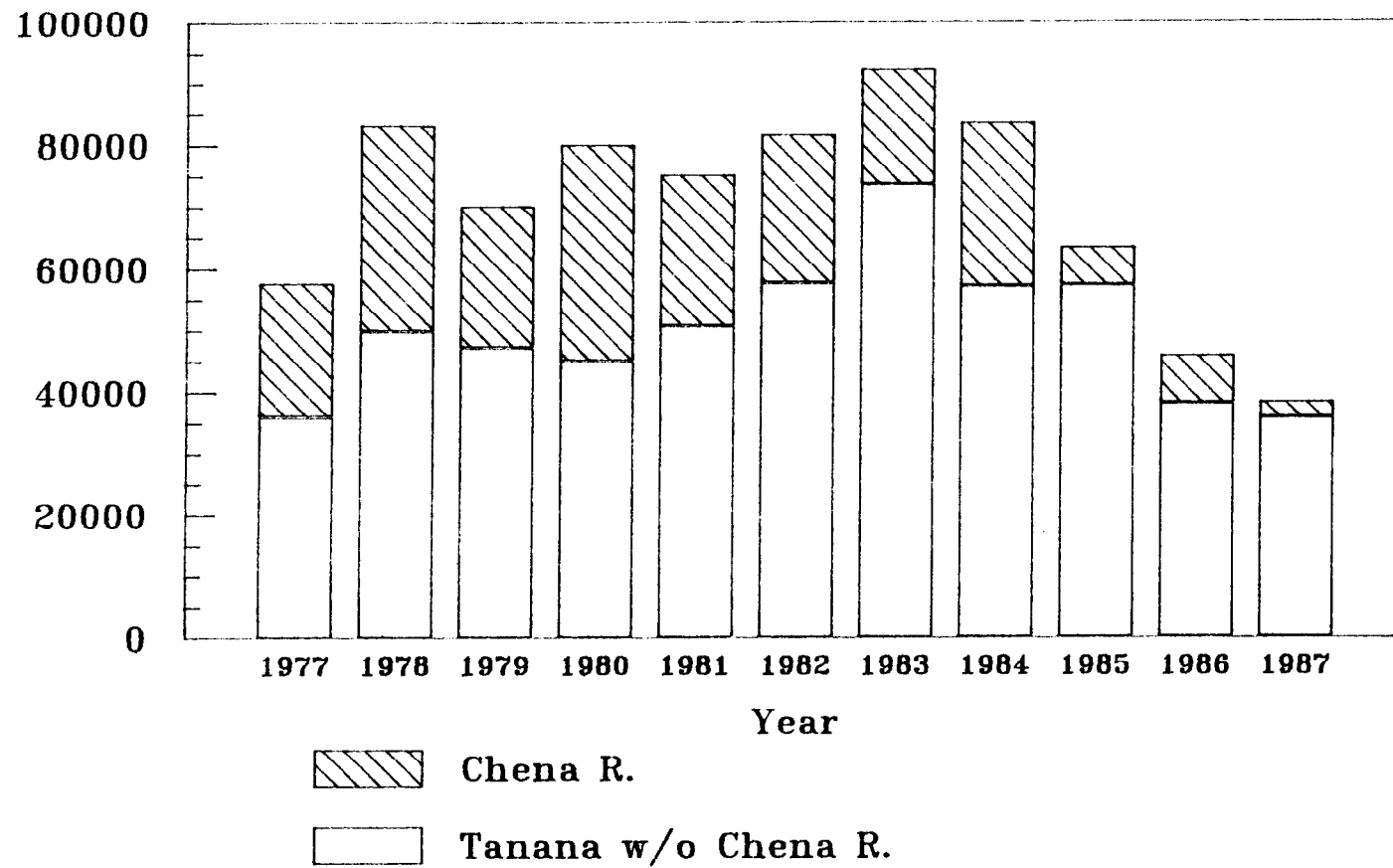
Figure 1. Annual harvests of Arctic grayling in the Chena River and in the entire Tanana drainage excluding the Chena River, 1977-1987 (taken from Mills 1979-1988).

INTRODUCTION

Background

The Chena River supports one of the largest Arctic grayling fisheries in North America. For the nine year period from 1979 to 1987, the Chena River produced an average annual sport harvest of 18,736 Arctic grayling in 26,386 man-days of angling effort (Table 1). As recently as 1984, annual harvests had exceeded 20,000 fish and 30,000 man-days of effort and harvests of Arctic grayling from the Chena River comprised a substantial portion of total Arctic grayling harvests in the Tanana River drainage (Figure 1). However, the status of this fishery has changed since 1984. Recreational harvest of Arctic grayling has declined to historic low levels. Harvest decreased 76% from 1984 to 1985, although angling effort had decreased only 39% (Table 1). Angling effort returned to an average level in 1986, but harvest remained below 10,000 fish. Concomitant with the declining recreational fishery was the decline in Arctic grayling population abundance. Stock assessment projects during 1986 (Clark and Ridder 1987a) and 1987 (Clark and Ridder 1988) documented a decline in population abundance of 49% between these two years. Poor recruitment was the probable cause for a decline in abundance (Holmes 1984; Holmes et al. 1986).

During winter of 1986, fishery managers were scheduled to present stock status data (Clark 1986) on the Chena River fishery to the Alaska Board of Fisheries. The Board of Fisheries meeting adjourned before the data could be presented. In spring of 1987, increased concern for the health of the Chena River stock prompted fishery managers to process emergency regulations to reduce harvest. These emergency regulations were:

   1)   closure of the fishery until the first Saturday in June;

   2)   a 12 inch (305 mm) minimum length limit; and,

   3)   restriction of terminal gear to unbaited artificial lures.

These emergency regulations were made permanent regulations in the summer of 1987. During the winter of 1987, fishery managers presented stock status and regulatory concerns to the Alaska Board of Fisheries (Clark 1987). The emergency regulations imposed in spring of 1987 were adopted and amended. The new permanent regulations were:

   1)   catch-and-release fishing from 1 April to the first Saturday in June;

   2)   a 12 inch (305 mm) minimum length limit from the first Saturday in June until 31 March;

   3)   restriction of terminal gear to unbaited artificial lures only throughout the Chena River, and bait fishing allowed downstream of the Moose Creek Dam with hooks having a gap larger than 0.75 inch (19 mm);

METHODS

Sampling Gear and Techniques

All sampling was performed with a pulsed-DC (direct current) electrofishing system mounted on a 6.1 m long river boat as previously described by Lorenz (1984). Input voltage (240 VAC) was provided by a 3,500 W single-phase gas powered generator (Homelite Model HG3500). A variable voltage pulsator (Coffelt Manufacturing Model VVP-15) was used to generate output current. Anodes were constructed of 9.5 mm diameter and 1.5 m long twisted steel cable. Four anodes were attached to the front of a 3 m long "T-boom" attached to a platform at the bow of the river boat. The aluminum hull of the river boat was used as the cathode.

Output voltages during sampling varied from 200 to 300 VDC. Amperage varied from 2.0 to 4.0 A. Duty cycle and pulse rate were held constant at 40% and 80 Hz, respectively. These operating characteristics were presumed to minimally affect Arctic grayling survival during mark-recapture experiments. Holmes and McBride (in prep.) found that mortality and injury rates of Arctic grayling were lower for pulsed-DC electroshock than for their control gears (hook-and-line and seine).

Sampling was conducted along the banks of the Chena River. The electrofishing boat was directed downstream along each bank, collecting all Arctic grayling seen, when possible. Captured Arctic grayling were held in an aerated holding tub to reduce capture related stress. The selected areas of the Chena River were sampled no more than once per day to prevent changes in capture probabilities of marked fish (Cross and Stott 1975). Each Arctic grayling was measured to the nearest 1 millimeter FL. A sample of scales was taken from the preferred zone[1] of each newly captured Arctic grayling. Arctic grayling greater than 149 mm FL were marked with individually numbered Floy FD-68 internal anchor tags inserted at the base of the dorsal fin. The tip of the left pelvic fin was removed to identify marked fish in case the numbered tag was shed. If any captured Arctic grayling exhibited signs of injury or imminent mortality, they were immediately sacrificed. Sacrificed fish were examined for sex and maturity, and the sagittal otoliths removed for comparison with age determined by scales.

Population Abundance

The abundance of Arctic grayling greater than 149 mm FL was estimated by mark-recapture techniques in the lower 152 km of the mainstem Chena River. Two sections of the Chena River were delineated for separate estimation experiments. Delineation of the Chena River was necessary because Tack (1980) and Clark and Ridder (1989) found increasing density of Arctic grayling with increasing distance upstream. Based on differences in population density from downstream to upstream areas of the Chena River, the lower 152 km of the Chena River is divided into Lower and Upper sections for estimating abundance and

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[1] The preferred zone for Arctic grayling is an area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin.

4) catch-and-release fishing year around from river kilometer 140.8 downstream to river kilometer 123.2; and,

5) reduce the possession limit from 10 to 5 fish (Tanana drainage-wide regulation).

The regulations adopted by the Board of Fisheries in winter of 1987 were the first changes in Arctic grayling management since 1975, when the daily bag limit was decreased from 10 to 5 fish. Evaluation of the effects of new regulations on the Arctic grayling stock and recreational anglers was begun in 1987.

Stock Assessment Goals and Objectives

Much of what is known about Arctic grayling population dynamics comes from research conducted in the Tanana drainage and particularly the Chena River. Stock status of Arctic grayling in the Chena River is measured on an annual basis, primarily during late June and all of July. Population abundance, age composition, size composition, growth, recruitment, and survival are estimated each year to determine the health of the stock. The long-term goals of stock assessment on the Chena River are to:

1) accurately and precisely describe the stock status of Chena River Arctic grayling on an annual basis;

2) use stock status data in models that predict the consequences of regulatory actions; and,

3) provide fishery managers with stock status data and model results so that informed management decisions can be made.

As stock status data are collected over a series of years, predictive models can be created to determine the effects of sport fishing on the Arctic grayling stock. The success of modelling efforts is dependent on the accuracy and precision of stock status data. If the first two goals are successful, the third goal is essentially fulfilled. Therefore, attainment of the first goal is essential to the management process and future health of the stock.

As part of attaining the first stock assessment goal, the objectives of the 1988 research efforts were to:

1) estimate the absolute abundance of Arctic grayling greater than 149 mm fork length (FL) in the lower 152 km of the Chena River;

2) estimate the age composition of Arctic grayling in the lower 152 km of the Chena River; and,

3) estimate Relative Stock Density (RSD) of Arctic grayling in the lower 152 km of the Chena River.

age composition. Downstream from the Moose Creek Dam complex to the mouth of the Chena River was designated the Lower Chena River (72 km long; Figure 2). Upstream from the dam to the second bridge on the Chena Hot Springs Road (kilometer 63.2) was designated the Upper Chena River (80 km long; Figure 3). Population abundance estimates pertain only to these two sections of the Chena River, excluding Badger Slough, the Little Chena River, and the South Fork of the Chena River.

Lower Chena River:

Population abundance in the Lower Chena River was estimated by expansion of abundance estimates in four 3.2 km-long sample areas (Clark and Ridder 1987b, 1988), utilizing a stratified design (Cochran 1977). Expansion of these estimates was accomplished by first subdividing the Lower Chena River into two subsections. Each subsection was chosen on the basis of river morphology and hydrologic characteristics that might influence Arctic grayling density. The first subsection (Lower Chena A) encompassed the lower 40 km of river. The second subsection encompassed 32 km below the Moose Creek Dam complex. Two of the four 3.2-km sample areas were randomly chosen in each of the subsections (2 strata, 2 samples per stratum). Sampling took place between 26 June and 8 July.

Multiple-sample population estimates were performed in each of the 3.2-km sample areas. Two of the areas were sampled once each day during a five day time span. Capture histories from each sample area were used as input to program CAPTURE (White et al. 1982). Program CAPTURE was used to perform a rigorous examination of assumptions necessary to multiple-sample abundance estimators. The assumptions necessary for accurate estimation of abundance in a closed population are (from Seber 1982):

1) the population is closed (no change in the number of Arctic grayling in the population during the estimation experiment);

2) all Arctic grayling have the same probability of capture in the first sample or in the second sample, or marked and unmarked Arctic grayling mix randomly between the first and second samples;

3) marking of Arctic grayling does not affect their probability of capture in the second sample;

4) Arctic grayling do not lose their mark between sampling events; and,

5) all marked Arctic grayling are reported when recovered in the second sample.

Assumption 1 could not be tested directly, but was implicitly assumed because of the short duration of the experiment (five days). Assumption 2 was tested with statistical procedures within program CAPTURE and with a Kolmogorov-Smirnov (Conover 1980) statistical test. Assumption 3 was tested for validity by program CAPTURE. Assumption 4 was assured of validity by double marking of Arctic grayling. Assumption 5 was assumed to be valid by rigorous examination of all Arctic grayling captured and by double marking.
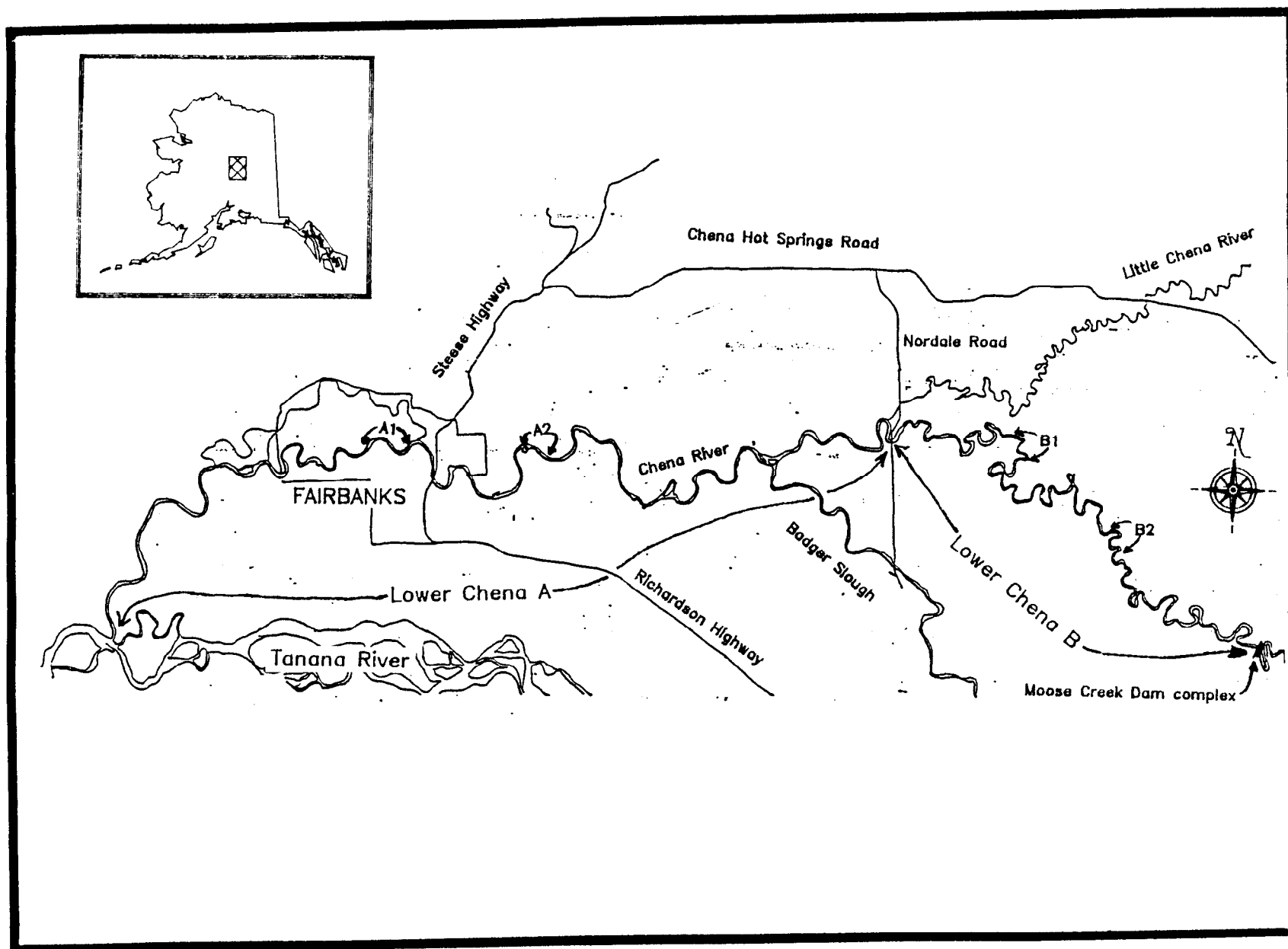
Figure 2. The Chena River below the Moose Creek Dam complex (Lower Chena River section).

FAIRBANKS 24 km

North Fork Chena River

Chena Hot Springs Road

Mullen Slough

Chena River

South Fork Chena River

Moose Creek Dam complex

Upper Chena Section
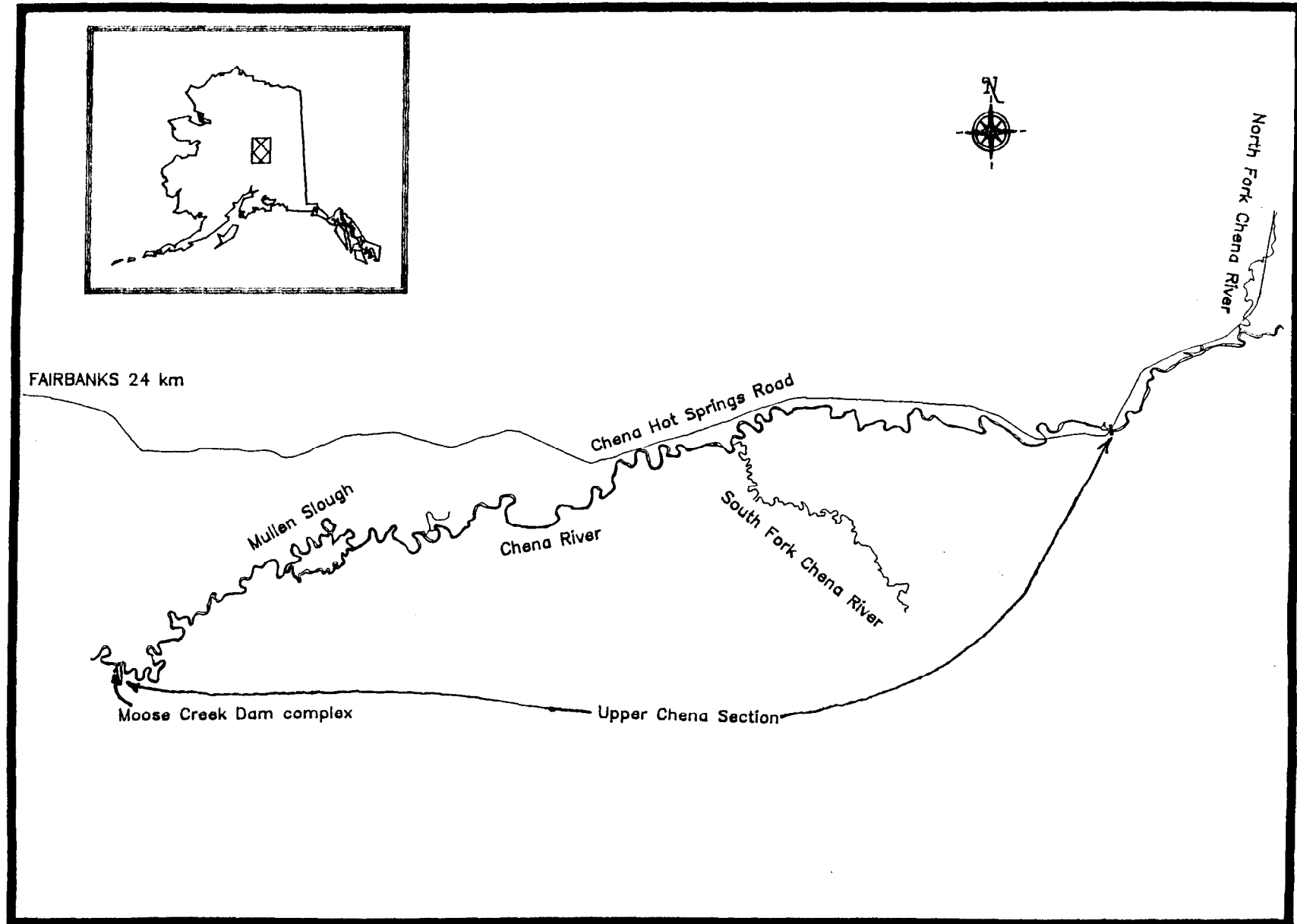
Figure 3. The Chena River above the Moose Creek Dam complex (Upper Chena River section).

Population abundance in the Lower Chena River was estimated by expanding the sample area estimates in each of the two subsections:

$$(1) \quad \hat{N}_i = R_i \hat{\bar{N}}_i$$

where: $\hat{N}_i$ = the estimated abundance in stratum (subsection) i;

R_i = the possible number of sample areas in stratum i;

$$\hat{\bar{N}}_i = \frac{\sum\limits_{j=1}^{r} \hat{N}_{ij}}{r_i} = \text{average abundance in } r \text{ 3.2-km sample areas};$$

r_i = 2 3.2-km sample areas in statum i;

$\hat{N}_{ij}$ = the abundance of Arctic grayling in sample area j of stratum i;

i = 1, 2 strata (Lower Chena A and Lower Chena B); and,

j = 1, 2 sample areas (A1 and A2, B1 and B2).

Lower Chena A had 12.5 possible 3.2-km sample areas (R_1 = 12.5) and Lower Chena B had 10 possible 3.2-km sample areas (R_2 = 10). The variance of each subsection abundance estimate was (Cochran 1977):

$$(2) \quad V[\hat{N}_i] = R_i[R_i - r_i] \hat{S}_i^2 + \frac{R_i^2}{r_i^2} \frac{r_i}{\sum\limits_{j=1}} V[\hat{N}_{ij}]$$

where: $V[\hat{N}_i]$ = variance of estimated abundance in stratum i;

$$\hat{S}_i^2 = \frac{\sum\limits_{j=1}^{r_i} (\hat{N}_{ij} - \hat{\bar{N}}_i)^2}{r_i(r_i - 1)};$$

$V[\hat{N}_{ij}]$ = variance of estimated abundance in sample area j of stratum i (from program CAPTURE); and,

r_i = the number of 3.2-km sample areas sampled in stratum i.

Equations 1 and 2 were used to estimate abundance and variance in subsections Lower Chena A and Lower Chena B. Equation 2 is probably a conservative estimate of variance for the Lower Chena. Estimated abundance and variance of the Lower Chena section was calculated by summing the subsection (stratum) abundance estimates and summing the variances:

$$(3) \quad \hat{N}_L = \sum\limits_{i=1}^{2} \hat{N}_i$$

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$$(4) \quad V[\hat{N}_L] = \sum_{i=1}^{2} V[\hat{N}_i]$$

where: $\hat{N}_L$ = estimate of Arctic grayling abundance in the Lower Chena
River; and,

$V[\hat{N}_L]$ = estimated variance of abundance of Arctic grayling in the Lower Chena River.

Upper Chena River:

Abundance of Arctic grayling greater than 149 mm FL was estimated with the modified Petersen estimator of Bailey (1951, 1952). Two electrofishing boats were used to mark Arctic grayling along both banks of the entire 80 km of the Upper Chena River. Marking of fish required four days. After a hiatus of seven days the two electrofishing boats were used in the same way to examine Arctic grayling for marks. The entire experiment was conducted between 25 and 28 July for the first sample and 1 and 4 August for the second (recapture) sample.

Assumptions necessary for accurate estimation of abundance were identical to those listed in the Lower Chena River experiments. Assumption 1 was implicitly assumed because of the large size of the sample area (80 km) and short duration of the experiment (two weeks). Assumptions 2 and 3 were tested with two Kolmogorov-Smirnov statistical tests. The first test compared the length frequency distributions of recaptured Arctic grayling with those captured during the marking run. The second test compared the length frequency distributions of Arctic grayling captured during the marking run with those captured in the recapture run. In addition, sampling was conducted with equal effort along the entire 80 km of river, so it was assumed that all Arctic grayling had equal probability of capture throughout the Upper Chena River section. Assumptions 4 and 5 were assumed to be valid because of double marking of tagged Arctic grayling and rigorous examination of all captured Arctic grayling.

Estimated abundance was calculated from numbers of marked, examined for marks, and recaptured (Bailey 1951; Seber 1982):

$$(5) \quad \hat{N}_U = \frac{M(C+1)}{(R+1)} - 1$$

where: M = the number of Arctic grayling marked and released alive during the first sample;

C = the number of Arctic grayling examined for marks during the second sample;

R = the number of Arctic grayling recaptured during the second sample; and,

$\hat{N}_U$ = estimated abundance of Arctic grayling during the first sample.

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Bailey's (1951, 1952) modification was used instead of the more familiar modification by Chapman (1951) because of the sampling design used on the Upper Chena River section. Seber (1981) found that if the assumption of a random sample for the second sample was false and a systematic sample was taken (for example, a systematic sample of both banks of the Chena River), then the binomial model of Bailey (1951, 1952) is most appropriate. The binomial model will hold in this situation when:

1) there is uniform mixing of marked and unmarked fish; and,

2) all fish, whether marked or unmarked, have the same probability of capture.

The Upper Chena River section sample design does not allow for thorough mixing of fish marked at the uppermost reaches with those marked in the downstream reaches, although local mixing of marked and unmarked fish probably occurs.

Variance of the abundance estimate was estimated by (Bailey 1951, 1952):

$$(6) \quad V[\hat{N}_U] = \frac{\hat{N}_U \, M \, (C - R)}{[(R + 1)(R + 2)]}.$$

Estimated abundance and variance in the entire Chena River was calculated as the sum of Lower Chena and Upper Chena River estimates:

$$(7) \quad \hat{N} = \hat{N}_L + \hat{N}_U \quad \text{and}$$

$$(8) \quad V[\hat{N}] = V[\hat{N}_L] + V[\hat{N}_U].$$

Age and Size Composition

Collections of Arctic grayling for age-length samples were conducted in conjunction with abundance estimation experiments. The Lower Chena River age-length samples were analyzed independently of the Upper Chena River age-length samples. A stratified design was used to derive age composition estimates for the Lower Chena River. This design was identical to the estimator for population abundance except that equations 1 through 5 were further partitioned into age classes. Therefore, abundance of age k Arctic grayling in the Lower Chena was estimated by equations 1 through 5. Using the estimates of abundance for age k ($k = 1, 2, 3, \ldots,$ n age classes) and the abundance estimates (N_i's), age composition of the Lower Chena River was estimated. First the proportions for each age class were estimated in each of the two sample areas for each of the two subsections of the Lower Chena:

$$(9) \quad \hat{P}_{ijk} = \frac{y_{ijk}}{n_{ij}}$$

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where: y_{ijk} = the number of age k Arctic grayling sampled in sample area j of subsection (stratum) i; and,

n_{ij} = the number of Arctic grayling sampled in sample area j of subsection i.

The variances of the proportions were estimated by:

$$(10) \quad V[\hat{P}_{ijk}] = \frac{\hat{P}_{ijk}(1 - \hat{P}_{ijk})}{n_{ij} - 1}$$

The sample area abundance estimates were used to weight each of the marginal proportions from the respective sample area:

$$(11) \quad \hat{N}_{ijk} = \hat{N}_{ij}\,\hat{P}_{ijk}$$

where: $\hat{N}_{ijk}$ = the estimated abundance of age k Arctic grayling in sample area j of stratum i.

The variance of this product was approximated by Goodman (1960):

$$(12) \quad V[\hat{N}_{ijk}] = \hat{P}_{ijk}\,V[\hat{N}_{ij}] + \hat{N}_{ij}\,V[\hat{P}_{ijk}] - V[\hat{P}_{ijk}]\,V[\hat{N}_{ij}]$$

By substituting N_{ijk} and $V[N_{ijk}]$ for N_{ij} and $V[N_{ij}]$ in equations 1 through 5, the resulting abundance estimates by age class $(N_{Lk}$'s) were used to estimate age composition for the Lower Chena River.

Proportion of the population by age class was calculated as:

$$(13) \quad \hat{P}_{Lk} = \hat{N}_{Lk} \div \hat{N}_{L}$$

where: $\hat{P}_{Lk}$ = the proportion of age k Arctic grayling in the Lower Chena River;

$\hat{N}_{Lk}$ = the abundance of age k Arctic grayling in the Lower Chena River (from substitution into equations 1 through 4); and,

$\hat{N}_{L}$ = the abundance of Arctic grayling in the Lower Chena River.

Bernard (1983) approximated the variance of the quotient of two dependent variables as (ignoring hat symbols):

$$(14) \quad V[P_{Lk}] = \left[\frac{N_{Lk}}{N_{L}}\right]^2 \left[\frac{V[N_{Lk}]}{N_{Lk}^2} + \frac{V[N_{L}]}{N_{L}^2} - \frac{2V[N_{Lk}]}{N_{L}\,N_{Lk}}\right]$$

Age composition of Upper Chena River Arctic grayling was calculated directly from age-length samples taken during the first sample of the mark-recapture estimate. The proportions and variances at age were calculated using equations 9 and 10 (disregarding subscripts for sample areas and strata).

Estimates of age composition were then used to apportion the Upper Chena River population abundance estimate and its variance using equations 11 and 12. The resulting abundance estimates at age k (N_{Uk}'s) and variances ($V[N_{Uk}]$'s) were then added to the corresponding N_{Lk} and $V[N_{Lk}]$ to estimate abundance at age in the entire Chena River. Age composition and variance in the entire Chena River was then estimated by equations 13 and 14.

Size composition of Arctic grayling in the Chena River was characterized by the Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories for Arctic grayling are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and "trophy" (greater then 559 mm FL). Estimation of RSD for the Chena River follows that of age composition estimates (equations 1 through 14). RSD estimates and variances were calculated by substituting "age class k" with "RSD category k". Similarly, the Upper Chena River and entire Chena River estimates and variances were calculated with equations 9 through 14.

Growth

Growth of Chena River Arctic grayling was modelled with the von Bertalanffy growth equation (Ricker 1975), a nonlinear least-squares method. Age-length data collected between 1986 and 1988 were used to model growth. All samples were taken with the electrofishing boat during mark-recapture experiments in the months of June and July.

Mean length at age was calculated as the arithmetic mean fork length at each age for samples taken from 1986 to 1988. Variances were calculated using the normal distribution theory. The Marquardt (1963) compromise was used to fit the three parameters of the von Bertalanffy growth equation. These parameters are:

1) L_∞ is the length an average fish would achieve if it continued to live and grow indefinitely (Ricker 1975);

2) K is a constant that determines the rate of increase of growth increments (Ricker 1975); and,

3) t_0 represents the hypothetical age at which a fish would have zero length (Ricker 1975).

By allowing the parameters to range from 350 to 600 mm FL by 50 mm increments for L_∞; from 0.0 to 0.4 by 0.1 for K; and from -2.0 to 2.0 by 0.5 for t_0, the model was fitted a total of 270 times. The model with the smallest squared deviations provided the starting parameters for iterative solution of the equation. The resulting growth equation was compared to growth equations derived from data collected on Arctic grayling in the Salcha and Chatanika Rivers (Clark 1989). Comparisons of growth equations were made with Hotteling's T^2 as described by Bernard (1981).

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Survival and Recruitment

As of 1988, three years of population abundance and age composition estimates had been completed for the lower 152 km of the Chena River. These estimates were used to estimate survival and recruitment for two time periods; between 1986 and 1987, and between 1987 and 1988. Survival rate and recruitment were calculated for the Arctic grayling population defined as: "those Arctic grayling in the lower 152 km of the Chena River that are age 3 and older".

Annual recruitment was defined as the number of age 3 Arctic grayling added to the population between year i and year $i+1$ and alive in year $i+1$. Estimates of recruitment were calculated with population abundance estimates and estimates of the proportion of age 3 Arctic grayling in 1987 and 1988:

$$(15) \quad \hat{A}_{i,i+1} = \hat{N}_{i+1} \, \hat{P}_{3,i+1}$$

where: $\hat{A}_{i,i+1}$ = recruits entering the population between year i and year $i+1$ and alive in year $i+1$;

$\hat{N}_{i+1}$ = number of fish age 3 and older in the population in year $i+1$; and,

$\hat{P}_{3,i+1}$ = the proportion of age 3 Arctic grayling in the population in year $i+1$.

Variance of annual recruitment was estimated with equation 12, the variance of a product. With recruitment and population abundance estimates in years i and $i+1$, one can estimate survival rate between year i and year $i+1$:

$$(16) \quad \hat{S}_{i,i+1} = \frac{\hat{N}_{i+1} - \hat{A}_{i,i+1}}{N_i}$$

The variance of annual survival was approximated as the variance of a quotient of two independent variables with the delta method (Seber 1982; ignoring hat symbols):

$$(17) \quad V[S] = \left[\frac{N'_{i+1}}{N_i} \right]^2 \left[\frac{V[N'_{i+1}]}{N'^{2}_{i+1}} + \frac{V[N_i]}{N_i^2} \right]$$

where: N'_{i+1} = $N_{i+1} - A_{i,i+1}$; and,

$V[N'_{i+1}] = V[N_{i+1}] + V[A_{i,i+1}]$.

Historic Data Summaries

Data collected from the Chena River (1955 to 1988) were summarized in Appendix A. Creel census estimates, population abundance estimates, length at age estimates, age composition estimates, and size composition estimates were summarized from Federal Aid in Sport Fish Restoration reports and State of Alaska Fishery Data Series reports written from 1959 to the present

(Appendix A). When possible, estimates of precision were reported with point estimates. Precision was reported as either standard error or 95% confidence interval. Sample sizes were reported if neither of these estimates of precision were available. Length frequency was generally reported in the literature as numbers sampled per 10 mm length increment. The length frequency distributions were converted into the RSD categories of Gabelhouse (1984) for comparison with data collected from 1986 to 1988. In addition to the aforementioned reports in Appendix A, Arctic grayling migration studies were summarized in a report by Tack (1980). Reports concerning Arctic grayling research from 1952-1980 were compiled by Armstrong (1982). In addition, Armstrong et al. (1986) have compiled a bibliography for the genus *Thymallus* to 1985.

RESULTS

Lower Chena River

A total of 627 Arctic grayling ($\geq$ 150 mm FL) was captured during mark-recapture experiments in the Lower Chena River. Twelve mortalities or serious injuries were recorded for an overall injury rate of 1.9% (SE = 0.5%).

Although no significant changes in capture probabilities by length of fish occurred during population estimation (Figure 4), program CAPTURE detected significant changes in behavior of marked Arctic grayling as the experiments progressed (Table 2). In two sample areas, variability in capture probability was attributed to two causes (see White et al. 1982). In sample area A1, CAPTURE found both temporal and behavioral components to change in capture probability during the experiment. Looking at the Kolmogorov-Smirnov plots of cumulative distributions (CDF; Figure 4), a change in capture probability was evident at approximately 219 mm FL. Although the two distributions were not significantly different, complete stratification of the experiment at 219 mm FL resulted in two separate populations for which CAPTURE could provide valid estimators. The estimate for small Arctic grayling contained a significant temporal component to changing capture probabilities (estimated abundance = 430). The estimate for large Arctic grayling contained primarily a behavioral component to changing capture probabilities (estimated abundance = 107). Estimated abundance in sample area A1 was 537 Arctic grayling (SE = 129 Arctic grayling, CV^2 = 24.0%; Table 2)

The same pattern of change in capture probabilities was evident in sample area B1. In this case the mark-recapture data were stratified at 234 mm FL as indicated by the CDF plot (Figure 4). No significant changes in capture probability were detected for small Arctic grayling (estimated abundance = 241). Large Arctic grayling in sample area B1 exhibited a behavioral change in capture probability (estimated abundance = 82). Estimated abundance in sample area B1 was 323 Arctic grayling (SE = 80 Arctic grayling, CV = 24.8%; Table 2).

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[2] CV = standard error (SE) divided by the point estimate expressed as a percentage.
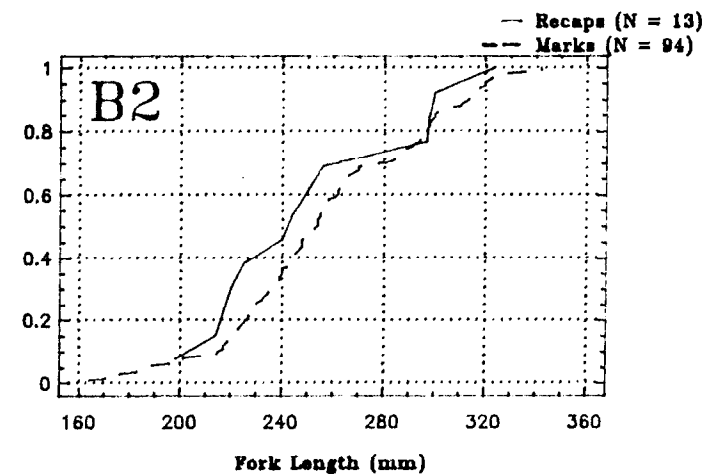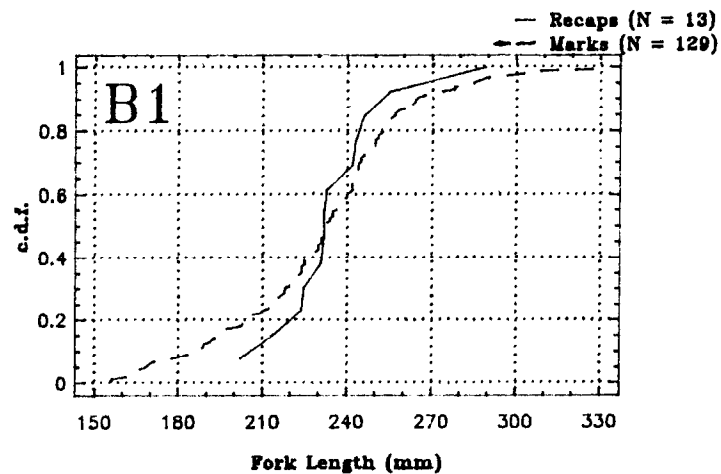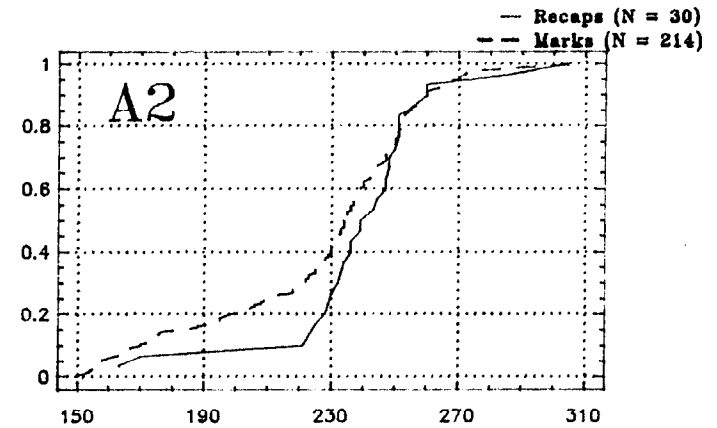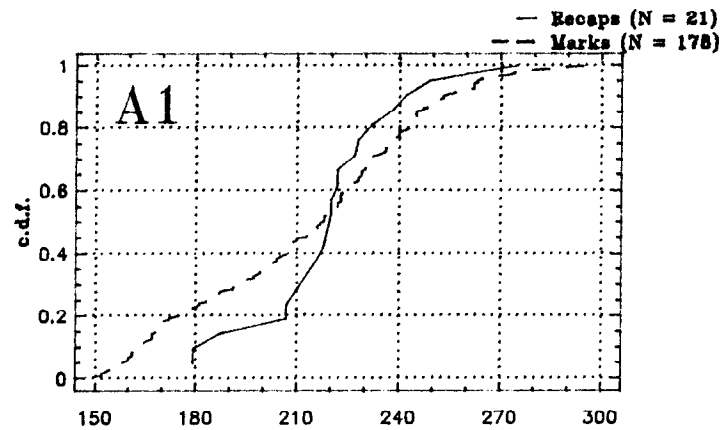
Figure 4. Cumulative distribution functions (c.d.f.) of lengths of Arctic grayling marked versus lengths of Arctic grayling recaptured for four 3.2-km sample areas of the Lower Chena section of the Chena River, 26 June through 8 July 1988. Kolmogorov-Smirnov test statistics and tail probabilities for each sample area are: A1(DN = 0.275; P = 0.11); A2(DN = 0.233, P = 0.11); B1(DN = 0.219, P = 0.99); and, B2(DN = 0.192, P = 0.99). N = sample size.

Table 2. Summary of sample area abundance estimates of Arctic grayling ($\geq$ 150 mm FL) in the Lower Chena section of the Chena River, 26 June through 8 July, 1988.

Subsection	River KM	CAPTURE Model[1]	Abundance Estimate	Standard Error	Fish/km
A1	14.4 to 17.6	M_t, M_{bh}[2]	537	129	168
A2	22.4 to 25.6	M_b	347	56	108
B1	48.0 to 51.2	M_o, M_b[3]	323	80	101
B2	57.6 to 60.8	M_b	124	17	39

[1] Models selected by program CAPTURE as most appropriate:
   M_t : time varying probability of capture;
   M_{bh}: behavioral and heterogeneous changes in probability of capture;
   M_b : behavioral changes in probability of capture; and,
   M_o : constant probability of capture.
These models and their estimators are described in White at al. (1982) and Otis et al. (1978).

[2] Model M_t was chosen for fish greater than 149 mm FL and less than 220 mm FL. Model M_{bh} was chosen for fish greater than 219 mm FL.

[3] Model M_o was chosen for fish greater than 149 mm FL and less than 235 mm FL. Model M_b was chosen for fish greater than 234 mm FL.

In sample areas A2 and B2, program CAPTURE estimated population abundance without stratification by length. In sample areas A2 and B2 a significant behavioral component caused a change in capture probability. Model M_b (Otis et al. 1978) was chosen as most appropriate for both sample area abundance estimates. Estimated abundance in sample area A2 was 347 Arctic grayling (SE = 56 Arctic grayling, CV = 16.1%; Table 2). Estimated abundance in sample area B2 was 124 Arctic grayling (SE - 17 Arctic grayling, CV - 13.7%; Table 2).

Expansion of estimated abundance in sample areas A1 and A2 resulted in an estimated population size of 5,525 Arctic grayling in subsection A of the Lower Chena River (Table 3). Expansion of estimates in sample areas B1 and B2 to all of subsection B resulted in an estimate of 2,235 Arctic grayling (Table 3). Estimated abundance of Arctic grayling in the Lower Chena River was 7,760 fish (SE = 1,707 fish, CV - 22.0%).

Age composition of samples taken from sample areas A1 and A2 of subsection A of the Lower Chena River were significantly different (χ^2 = 35.45, df = 4, P < 0.005; Figure 5, Table 4). A significant difference was also found in samples taken from sample areas B1 and B2 of subsection B (χ^2 = 20.85, df = 6, P < 0.005; Figure 5, Table 4). Therefore, age composition data were expanded by sample area to adjust for differences in age composition within subsections. Age 5 Arctic grayling dominated the estimated age composition of the Lower Chena River in 1988. Of the estimated 7,760 Arctic grayling in the Lower Chena River, 3,126 fish (SE = 653 fish, CV - 20.9%), or 40.3% were age 5 (Table 4). Abundances of age 2 through age 4 Arctic grayling were similar. The abundance estimate for age 2 fish was most likely biased because of the imposed lower length limit for mark-recapture experiments (150 mm FL). The estimate of age 3 abundance probably reflected the true abundance of this age class. Very few Arctic grayling older than age 5 were found in the Lower Chena River (Table 4).

Size composition samples taken from subsection A were not significantly different (χ^2 = 0.44, df = 1, P > 0.50; Figure 6, Table 5). However, size composition estimates in the two sample areas in subsection B were significantly different (χ^2 = 23.14, df = 1, P < 0.005; Figure 6, Table 5). Therefore, size composition data were expanded by sample area to adjust for differences in size composition within subsection B. Ninety-two percent of Arctic grayling greater than 149 mm FL were also less than 270 mm FL (Table 5). Of the 594 Arctic grayling (SE = 104 fish, CV = 17.5%) greater than 270 mm FL, only 10 fish (SE = 12 fish, CV = 120.0%) were of preferred size ($\geq$ 340 mm FL). No memorable or trophy size Arctic grayling were sampled from the Lower Chena River.

Upper Chena River

A total of 2,495 Arctic grayling ($\geq$ 150 mm FL) was captured during the mark-recapture experiment on the Upper Chena River. Twenty-eight mortalities or serious injuries were recorded for an overall injury rate of 1.1% (SE = 0.2%).

During 25 through 28 July, 1,291 Arctic grayling ($\geq$ 150 mm FL) were marked along 80 km of the Upper Chena River. During 1 through 4 August, 1,307 Arctic

Table 3. Estimated abundance of Arctic grayling ($\geq$ 150 mm FL) in the lower 72 kilometers of the Chena River (Lower Chena section), 26 June through 8 July, 1988.

Subsection	Subsection Length (km)	Estimated Abundance	Variance	Standard Error
A1	3.2	537	16,563	129
A2	3.2	347	3,115	56
Average	3.2	442	9,025	95
Total	40.0	5,525	1,953,218	1,398
B1	3.2	323	6,396	80
B2	3.2	124	295	17
Average	3.2	224	9,900	100
Total	32.0	2,235	959,297	979
Lower Chena	72.0	7,760	2,912,514	1,707
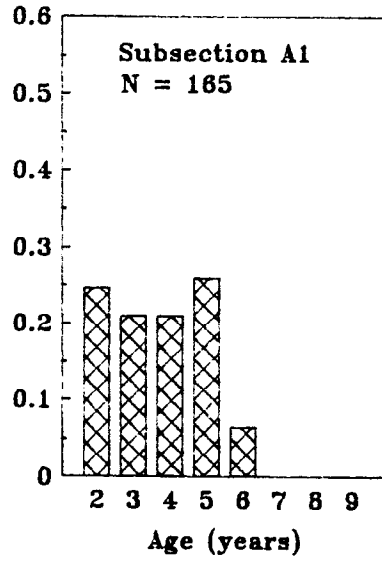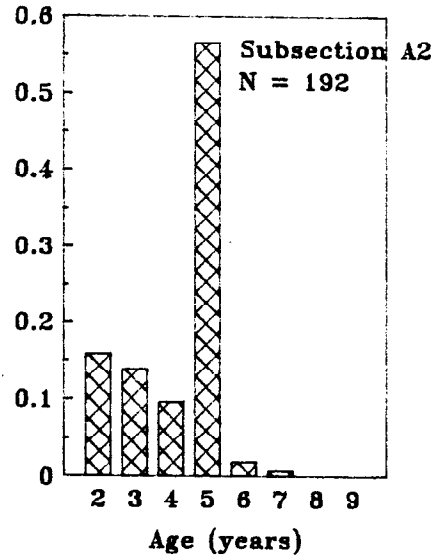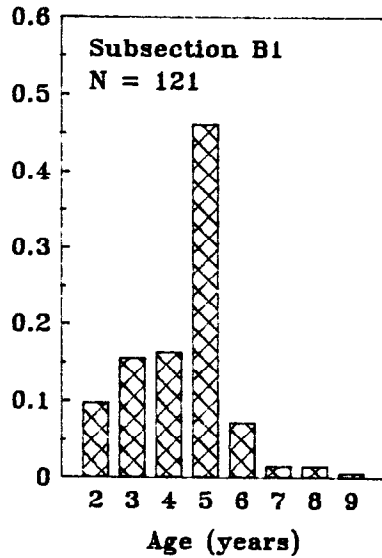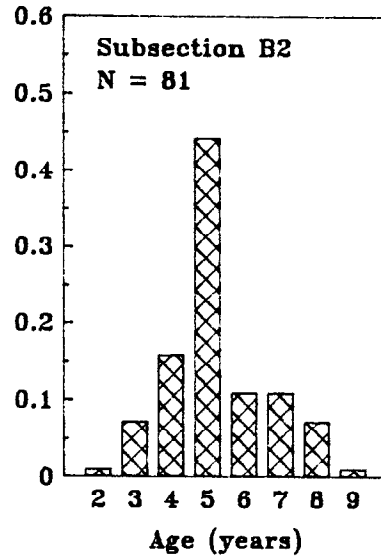
Figure 5. Age compositions of Arctic grayling sampled from each of four 32.2-km sample areas of the Lower Chena section of the Chena River, 26 June through 8 July 1988 (N = sample size).

Table 4. Estimates of age composition and and abundance by age with standard errors from Arctic grayling (greater than 149 mm FL) captured by pulsed-DC electrofishing in the Lower Chena section of the Chena River, 27 June to 8 July 1988.

Age	Subsection A1[1] n[6]	p[7]	SE[8]	N[9]	SE[10]	Subsection A2[2] n	p	SE	N	SE	Subsection B1[3] n	p	SE	N	SE	Subsection B2[4] n	p	SE	N	SE	Lower Chena[5] p	SE	N	SE
2	41	0.248	0.034	133	36	31	0.161	0.027	56	13	12	0.099	0.027	32	12	1	0.012	0.012	2	2	0.174	0.067	1,351	524
3	35	0.212	0.032	114	32	27	0.141	0.025	49	12	19	0.157	0.033	51	16	6	0.074	0.029	9	4	0.170	0.062	1,319	476
4	35	0.212	0.032	114	32	19	0.099	0.022	34	9	20	0.165	0.034	53	27	13	0.160	0.041	20	6	0.166	0.067	1,290	532
5	43	0.261	0.034	140	38	109	0.568	0.036	197	34	56	0.463	0.046	149	40	36	0.444	0.056	55	10	0.403	0.096	3,126	653
6	11	0.067	0.019	36	13	4	0.021	0.010	7	4	9	0.074	0.024	24	10	9	0.111	0.035	14	5	0.059	0.027	459	200
7	0	0.000	0.000	0	0	2	0.010	0.007	4	3	2	0.017	0.012	5	4	9	0.111	0.035	14	5	0.015	0.008	120	58
8	0	0.000	0.000	0	0	0	0.000	0.000	0	0	2	0.017	0.012	5	4	6	0.074	0.029	9	4	0.009	0.005	70	33
9	0	0.000	0.000	0	0	0	0.000	0.000	0	0	1	0.008	0.008	3	3	1	0.012	0.012	2	2	0.003	0.002	25	16
Total	165	1.000	---	537	129	192	1.000	---	347	56	121	1.000	---	323	80	81	1.000	---	124	17	1.000	---	7,760	1,707

[1] Subsection A1 - River kilometer 14.4 to 17.6; 27 June to 1 July.
[2] Subsection A2 - River kilometer 22.4 to 25.6; 27 June to 1 July.
[3] Subsection B1 - River kilometer 48.0 to 51.2; 5 July to 8 July.
[4] Subsection B2 - River kilometer 57.6 to 60.8; 5 July to 8 July.
[5] Expansion to the entire Lower Chena section - River kilometer 0 to 72.0.
[6] n = number of Arctic grayling sampled at age.
[7] p = estimated proportion of Arctic grayling at age in the subsection.
[8] SE = estimated standard error of p (normal approximation to binomial).
[9] N = estimated subsection abundance of Arctic grayling at age.
[10] SE = estimated standard error of N.

Proportion of N
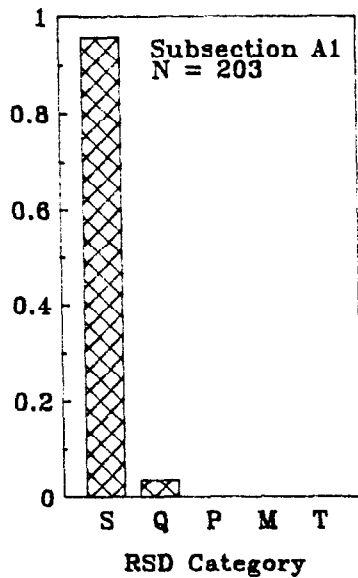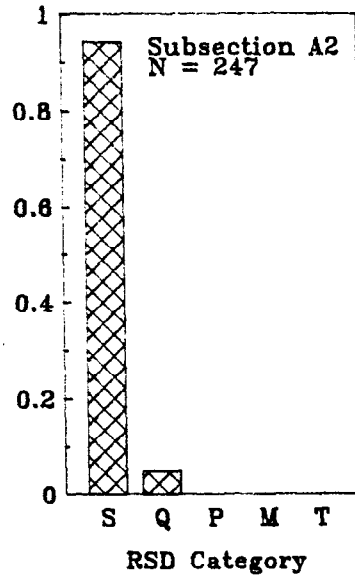
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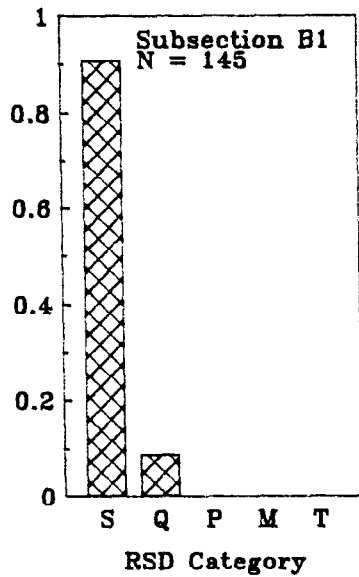
Proportion of N

Proportion of N
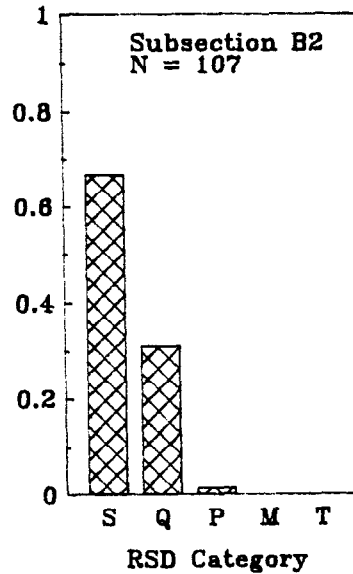
Figure 6.   Size composition of Arctic grayling sampled from each of four 3.2-km sample areas of the Lower Chena section of the Chena River, 26 June through 8 July 1988 (N - sample size; S - stock (150 to 269 mm FL), Q = quality (270 to 339 mm FL), P = preferred (340 to 449 mm FL), M = memorable (450 to 559 mm FL), and T = trophy (greater than 559 mm FL).

Table 5. Summary of Relative Stock Density (RSD) indices of Arctic grayling ($\geq$ 150 mm FL) captured in the Lower Chena section of the Chena River, 27 June to 8 July 1988.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
Subsection A1[2]					
Number sampled	195	8	0	0	0
RSD	0.961	0.039	0.000	0.000	0.000
Standard Error	0.014	0.014	0.000	0.000	0.000
Abundance[3]	516	21	0	0	0
Standard Error	124	9	0	0	0
Subsection A2					
Number sampled	234	13	0	0	0
RSD	0.947	0.053	0.000	0.000	0.000
Standard Error	0.014	0.014	0.000	0.000	0.000
Abundance	329	18	0	0	0
Standard Error	53	6	0	0	0
Subsection B1					
Number sampled	132	13	0	0	0
RSD	0.910	0.090	0.000	0.000	0.000
Standard Error	0.024	0.024	0.000	0.000	0.000
Abundance	294	29	0	0	0
Standard Error	73	10	0	0	0
Subsection B2					
Number sampled	73	34	2	0	0
RSD	0.670	0.312	0.018	0.000	0.000
Standard Error	0.045	0.045	0.013	0.000	0.000
Abundance	83	39	2	0	0
Standard Error	13	8	2	0	0
Lower Chena					
RSD	0.923	0.075	0.001	0.000	0.000
Standard Error	0.026	0.021	0.002	0.000	0.000
Abundance[4]	7,166	584	10	0	0
Standard Error	1,699	103	12	0	0

[1] Minimum lengths for RSD categories are (Gabelhouse 1984):
    Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL;
    Memorable - 450 mm FL; and, Trophy - 560 mm FL.

[2] Subsections are: A1 - River kilometer 14.4 to 17.6; A2 - River kilometer 22.4 to 25.6; B1 - River kilometer 48.0 to 51.2; and, B2 - River kilometer 57.6 to 60.8.

[3] Abundance is the estimated abundance in a 3.2 km subsection.

[4] Abundance is the expanded abundance estimate in the lower 72.0 km of the Chena River by RSD category.

grayling were examined for marks along the same 80 km section of river. A total of 116 Arctic grayling was recaptured during the second sample. No significant difference was found between the CDF of lengths of marked Arctic grayling and the CDF of lengths of recaptured Arctic grayling ($DN^3 = 0.11$, $P = 0.13$). Therefore, the second sample was unbiased with respect to equal probability of capture of marked Arctic grayling by size (Figure 7B) and a single population estimate would suffice. The modified Petersen estimate of Bailey (1951, 1952) was 14,444 fish (SE = 1,210 fish, CV = 8.4%).

The CDF of lengths of marked Arctic grayling was significantly different than the CDF of lengths of Arctic grayling examined for marks ($DN = 0.065$, $P = 0.007$), although no functional difference was evident (Figure 7A). It was therefore judged that age-length samples taken during the marking event could be used to directly estimate age and size compositions of Arctic grayling in the Upper Chena River. Age 5 Arctic grayling dominated the sample from the Upper Chena River, representing 43.6% of all fish sampled (Table 6). Age 3 and age 8 fish were next most abundant, accounting for 14.2% and 9.6% of the population, respectively.

Size composition of Arctic grayling in the Upper Chena River was split equally among stock size and quality size fish (Table 7). Over 50% of Arctic grayling greater than 149 mm FL were also greater than 269 mm FL. No memorable or trophy size Arctic grayling were sampled on the Upper Chena River.

Chena River

The summed estimate of Arctic grayling abundance in the lower 152 km of the Chena River was 22,204 fish (SE = 2,092 fish, CV = 9.4%). Of these fish, 42.4% were age 5, representing an abundance of 9,423 fish (Table 8). The next most abundant age class was age 3, totalling 3,373 fish or 15.2%. Although not fully recruited to the mark-recapture estimates, age 2 Arctic grayling represented 8.7% of the estimated abundance or 1,936 fish (SE = 533 fish, CV = 27.5%). Of the 22,204 Arctic grayling greater than 149 mm FL, 62.7% or 13,923 fish were less than 270 mm FL (Table 7). Of the remaining 8,281 fish that were greater than 269 mm FL, 1,200 fish (SE = 127 fish, CV = 10.6%) were also greater than 339 mm FL.

The von Bertalanffy growth model was successfully adapted to Chena River Arctic grayling collected from 1986 through 1988 (Table 9). Standard deviation of mean fork length was stable among all ages of fish sampled, although more samples were needed from age 10 and age 11 fish (Table 10). Growth of Chena River Arctic grayling was significantly different than Arctic grayling collected from either the Salcha River (Clark, in prep.; $T^2 = 121.53$; $df = 3$ and 5,495; $P < 0.01$) or the Chatanika River (Clark, in prep.; $T^2 = 90.93$; $df = 3$ and 5,766; $P < 0.01$) during the same three year time span.

Population size (age 3 and older) in summer of 1986 was 61,581 fish (SE = 26,987 fish, CV = 43.8%). Annual recruitment from summer 1986 to summer 1987 was 2,526 fish (SE = 358 fish, CV = 14.2%). Population size in summer of 1987 was 29,580 fish (SE = 3,525 fish, CV = 11.9%). Annual survival was

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[3] DN = test statistic for the Kolmogorov-Smirnov test.
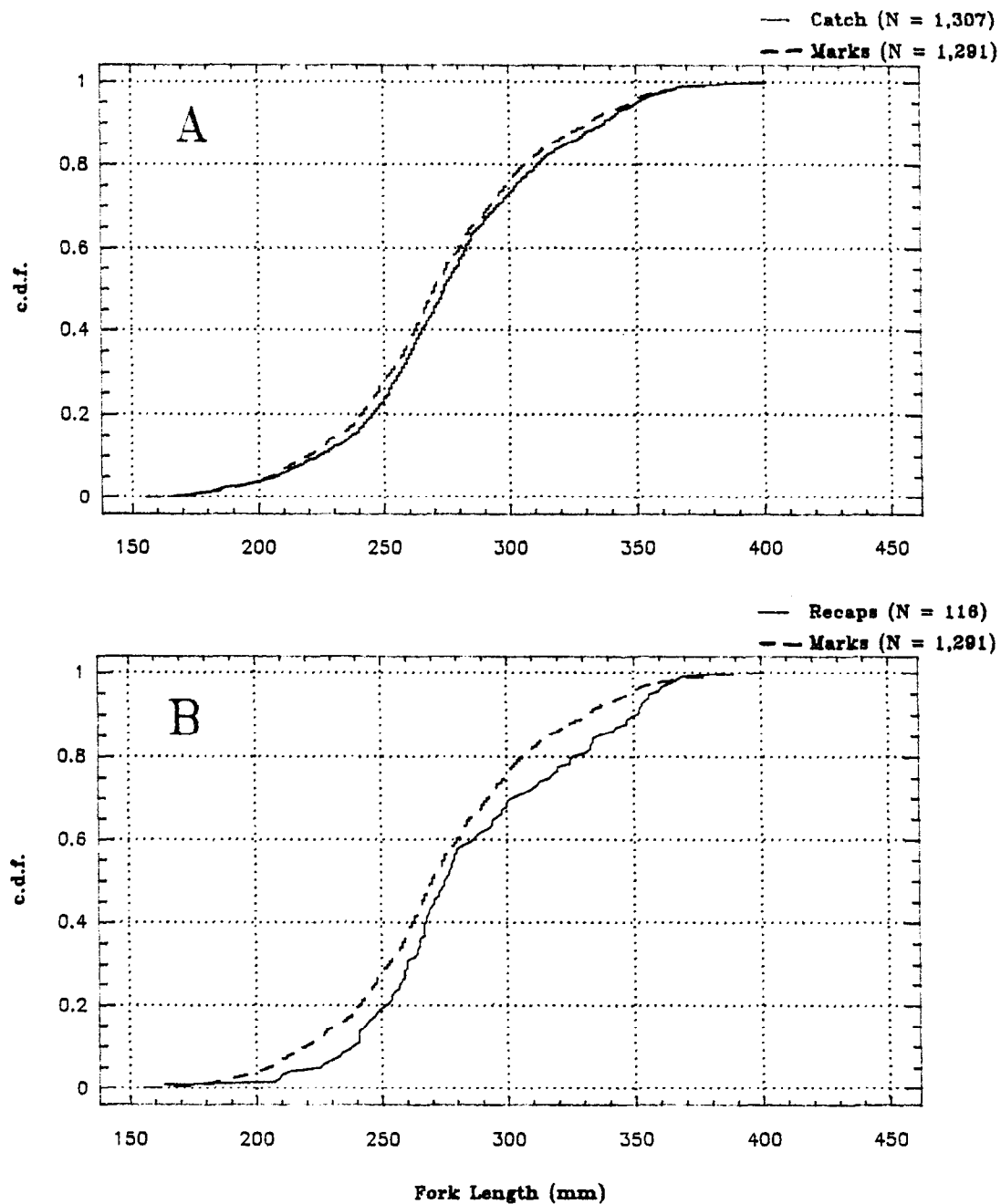
Figure 7. Cumulative distribution functions of lengths of Arctic grayling
marked versus lengths of Arctic grayling examined for marks (A) and
versus lengths of Arctic grayling recaptured (B) for the Upper
Chena section of the Chena River, 28 July through 4 August 1988.
Kolmogorov-Smirnov test statistics and tail probabilities are:
A(DN = 0.065, P = 0.007); and, B(DN = 0.114, P = 0.126).

Table 6. Estimates of age composition and abundance by age class with standard errors for Arctic grayling ($\geq$ 150 mm FL) captured by pulsed-DC electrofishing from the Upper Chena section of the Chena River, 25 to 28 July, 1988.

Age	n[1]	p[2]	SE[3]	CV[4]	N[5]	SE[6]	CV[7]
		Age Composition			Abundance		
2	43	0.040	0.006	15.0	585	100	17.1
3	151	0.142	0.011	7.7	2,054	231	11.2
4	94	0.089	0.009	10.1	1,278	165	12.9
5	463	0.436	0.015	3.4	6,297	571	9.1
6	85	0.080	0.008	10.0	1,156	154	13.3
7	82	0.077	0.008	10.4	1,115	150	13.4
8	102	0.096	0.009	9.4	1,387	175	12.6
9	33	0.031	0.005	16.1	449	85	18.9
10	7	0.007	0.002	28.6	95	37	38.9
11	2	0.002	0.002	100.0	27	19	70.4
Total	1,062	1.000	---	---	14,444	1,210	8.4

[1] n = number of Arctic grayling sampled at age.
[2] p = estimated proportion of Arctic grayling at age in the population.
[3] SE = estimated standard error of p (normal approximation to the binomial).
[4] CV = coefficient of variation of p, expressed as a percentage of p.
[5] N = estimated population abundance of Arctic grayling at age.
[6] SE = estimated standard error of N (Seber 1982).
[7] CV = coefficient of variation of N, expressed as a percentage of N.

Table 7. Summary of Relative Stock Density (RSD) indices of Arctic grayling ($\geq$ 150 mm FL) captured in the Lower and Upper Chena sections, and the Chena River, 1988.

| | RSD Category[1] | | | | |
	Stock	Quality	Preferred	Memorable	Trophy
Lower Chena					
RSD	0.923	0.075	0.001	0.000	0.000
Standard Error	0.026	0.021	0.002	0.000	0.000
Abundance	7,166	584	10	0	0
Standard Error	1,699	103	12	0	0
Upper Chena					
Number sampled	1,221	1,174	215	0	0
RSD	0.468	0.450	0.082	0.000	0.000
Standard Error	0.010	0.010	0.005	0.000	0.000
Abundance	6,757	6,497	1,190	0	0
Standard Error	583	562	126	0	0
Chena River					
RSD	0.627	0.319	0.054	0.000	0.000
Standard Error	0.043	0.034	0.007	0.000	0.000
Abundance	13,923	7,081	1,200	0	0
Standard Error	1,796	571	127	0	0

[1] Minimum lengths for RSD categories are (Gabelhouse 1984):
   Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL;
   Memorable - 450 mm FL; and, Trophy - 560 mm FL.

Table 8. Estimates of age composition and abundance by age with standard errors for Arctic grayling captured by pulsed-DC electrofishing from the Lower and Upper Chena sections and the Chena River, 1988.

Age	Lower Chena[1]				Upper Chena[2]				Chena River[3]			
	p[4]	SE[5]	N[6]	SE[7]	p	SE	N	SE	p	SE	N	SE
2	0.174	0.067	1,351	524	0.040	0.006	585	100	0.087	0.023	1,936	533
3	0.170	0.062	1,319	476	0.142	0.011	2,054	231	0.152	0.024	3,373	529
4	0.166	0.067	1,290	532	0.089	0.009	1,278	165	0.116	0.025	2,568	557
5	0.403	0.096	3,126	653	0.436	0.015	6,297	571	0.424	0.043	9,423	868
6	0.059	0.027	459	200	0.080	0.008	1,156	154	0.073	0.013	1,615	252
7	0.015	0.008	120	58	0.077	0.008	1,115	150	0.056	0.009	1,235	161
8	0.009	0.005	70	33	0.096	0.009	1,387	175	0.066	0.010	1,457	178
9	0.003	0.002	25	16	0.031	0.005	449	85	0.021	0.004	474	87
10	0.000	0.000	0	0	0.007	0.002	95	37	0.004	0.002	95	37
11	0.000	0.000	0	0	0.002	0.001	27	19	0.001	0.001	27	19
Totals	1.000	---	7,760	1,707	1.000	---	14,444	1,210	1.000	---	22,204	2,092

[1] Lower Chena section - River kilometer 0 to 72.0.
[2] Upper Chena section - River kilometer 72.0 to 152.0.
[3] Chena River - River kilometer 0 to 152.0.
[4] p = estimated proportion of Arctic grayling at age in the section.
[5] SE = estimated standard error of p.
[6] N = estimated population abundance of Arctic grayling at age in the section.
[7] SE = estimated standard error of N.

Table 9. Parameter estimates and standard errors of the von Bertalanffy growth model[1] for Arctic grayling from the Chena River, 1986-1988.

Parameter	Estimate	Standard Error
L_∞	538	21
K	0.096	0.007
t_o	-1.716	0.111
$Corr(L_\infty, K)$	-0.993	---
$Corr(L_\infty, t_o)$	-0.906	---
$Corr(K, t_o)$	0.947	---
Sample size	4,301	

[1] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $l_t = L_\infty (1 - exp(-K (t - t_o)))$. The parameters of this model were estimated with data collected during 1986 through 1988. Estimation was accomplished through nonlinear regression using the Marquardt compromise (Marquardt 1963).

Table 10. Mean fork length at age of Arctic grayling from the Chena River, 1986-1988.

Age	n^1	FL^2	SD^3	SE^4
1	99	130	27	3
2	311	168	22	1
3	1,092	192	23	1
4	951	227	23	1
5	932	260	23	1
6	347	281	26	1
7	321	310	29	2
8	162	324	26	2
9	71	342	28	3
10	10	341	22	7
11	5	368	27	12
Totals	4,301	235	54	1

[1] n is the total number of fish aged from samples taken in 1986, 1987, and 1988.
[2] FL is the arithmetic mean fork length in millimeters.
[3] SD is the sample standard deviation of FL.
[4] SE is the standard error of FL.

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estimated as 43.9% (SE = 20.1%, CV = 45.8%) between 1986 and 1987. Annual recruitment from summer 1987 to summer 1988 was 3,373 fish (SE = 529 fish, CV = 15.7%). Population size in summer of 1988 was 20,268 fish (SE = 1,214 fish, CV = 6.0%). Annual survival was estimated as 57.1% (SE = 8.1%, CV = 14.2%) between 1987 and 1988.

DISCUSSION

The sampling designs presented in this report were adequate for the precise estimation of population abundance, and age and size compositions. The objective criterion for population estimation was for the estimate to be within ± 25% of the true abundance 95% of the time. Although a 95% confidence interval was not calculated for this estimate, a coefficient of variation of 12% or less would meet or exceed the objective criterion. The coefficient of variation of estimated population abundance was 9.4%, although the imprecision of the Lower Chena River abundance estimate reduced overall precision. Imprecision of sample area abundance estimates was the cause of imprecision in the Lower Chena popultion estimate, although differences in population size within subsections accounted for a large portion of the variation in estimation (see Tables 2 and 3). Precision of the Chena River abundance estimate was primarily dependent on precision of the Upper Chena section estimate. High numbers of recaptures in the Upper Chena section relative to the Lower Chena section resulted in greater precision of the abundance estimate in the Upper Chena section.

If population size in the Lower Chena is truly unrelated to sample areas chosen, then a stratified design would not be as efficient in estimating population size for the entire Lower Chena section. If the four sample areas discussed in this report were truly randomly chosen, without regard for river subsection, then the estimated abundance would have been 7,487 fish with a standard error of 1,950 fish. From Table 2, one can see that population estimates in sample areas A2 and B1 were more similar than either A1 or B2, respectively. Improper construction of strata could reduce precision, (and possible accuracy) especially when the true distribution of population sizes by river section is entirely random.

Age and size compositions were estimated with high precision, primarily because of the high numbers of Arctic grayling sampled during mark-recapture experiments. Thompson (1987) recommended that a sample of at least 400 be taken to estimate multinomial proportions with sufficient precision (all proportions are within 10% of the true proportions 95% of the time, corresponding to a coefficient of variation of 5% or less). Over 1,000 samples were used for age composition in the Upper Chena River, so that standard errors are small for each proportion (Tables 6 and 8). However, because of the stratified design in the Lower Chena River and significant differences in age composition by sample area, standard errors were large for each proportion (Tables 4 and 8; Figure 5). Additional variation in age composition was introduced by variation due to the mark-recapture estimate and stratified design. Sample size by sample area ranged from 81 to 192 ages, hardly enough to satisfy Thompson's (1987) statistical criterion for each sample area. If age compositions were similar among sample areas, the data

could have been pooled and weighted by abundance alone (ignoring between strata variance) as was reported by Clark and Ridder (1988) in 1987.

Estimates of size composition in the Upper Chena River were relatively precise (Table 7). Sample size for the length frequency was over 2,000 in the Upper Chena River. However, RSD estimates in the Lower Chena suffered from small sample size by sample area (Table 5). Length data could have been pooled among sample areas, but one area (area B2) had a significantly different length frequency from all other sample areas (Table 5; Figure 6).

The ultimate goal of stock assessment research on the Chena River is to predict the effect of the recreational fishery on the Arctic grayling stock. Predictions can be made by analytically modelling stock dynamics and the fishery. By artificially manipulating the fishery, the consequences of management can be inferred from changes in the status of the stock. If the analytical model suffers from inadequate data input, predicted stock status output will also be inadequate. Inadequate data input is the result of a poor sampling design or the vagaries of sampling biological populations. As estimates of population abundance and age composition become more reliable, estimates of survival, fishing mortality, natural mortality, and annual recruitment will become more reliable. For example, estimated survival rate between 1986 and 1987 was imprecise (CV = 45.8%), although estimated survival between 1987 and 1988 was relatively precise (CV = 14.2%). Imprecision in the first estimate is due to imprecision in the 1986 estimate of abundance alone, since the 1987 abundance estimate was also used in the second estimate of survival. The 1986 abundance estimate was imprecise because of a poor sampling design (Clark and Ridder 1987b, 1988).

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APPENDIX A

Appendix Table A1. Source citations for Federal Aid and Fishery Data Reports used for data summaries, 1955-1988.

Year	Type of Data[1]	Source Document
1955	CC	Warner (1959)
1956	CC	Warner (1959)
1957	CC	Warner (1959)
1958	CC	Warner (1959)
1967	AL, CC, POP	Van Hulle (1968)
1968	AL, CC, POP	Roguski and Winslow (1969)
1969	AL, CC, POP	Roguski and Tack (1970)
1970	CC, POP	Tack (1971)
1971	POP	Tack (1972)
1972	CC, POP	Tack (1973)
1973	AL, POP	Tack (1974)
1974	AL, CC, POP	Tack (1975)
1975	AL, CC, POP	Tack (1976)
1976	AL, CC, POP	Hallberg (1977)
1977	AL, CC, POP	Hallberg (1978)
1978	AL, CC, POP	Hallberg (1979)
1979	AL, CC, POP	Hallberg (1980)
1980	AL, CC, POP	Hallberg (1981)
1981	AL, CC, POP	Hallberg (1982)
1982	AL, CC, POP	Holmes (1983)
1983	AL, CC, POP	Holmes (1984)
1984	AL, CC, POP	Holmes (1985)
1985	AL, CC, POP	Holmes et al. (1986)
1986	CC	Clark and Ridder (1987a)
	AL, POP	Clark and Ridder (1987b)
1987	CC	Baker (1988)
1987	AL, POP	Clark and Ridder (1988)
1988	CC	Baker (in prep.)
	AL, POP	Clark (this report)

[1] CC = Creel census estimates;
   AL = age and size composition estimates; and,
   POP = population abundance estimates.

Appendix Table A2. Chena River study sections used from 1968 to 1985[1].

Section Number	Section Name	River Kilometers	Length in Kilometers
1	River mouth to University Ave.	0-9.6	9.6
2A	University Ave. to Peger Road	9.6-12.8	3.2
2B	Peger Road to Wendell Street	12.8-17.6	4.8
3	Wendell St. to Wainwright Bridge	17.6-23.2	5.6
4	Wainwright Bridge to Badger Slough	23.2-34.4	11.2
5	Badger Slough		26.4
6	Badger Slough to Little Chena R.	34.4-39.2	4.8
7	Little Chena River		98.4
8	Little Chena to Nordale Slough	39.2-49.6	10.4
DS	Nordale Slough to Bluffs	49.6-88.8	39.2
9B	Bluffs to Bailey Bridge	88.8-100.8	12.0
10	Bailey Bridge to Hodgins Slough	100.8-126.4	25.6
11	Hodgins Slough to 90 Mi. Slough	126.4-144.0	17.6
12	90 Mi. Slough to First Bridge	144.0-147.2	3.2
13	First Bridge to Second Bridge	147.2-151.2	4.0
14	Second Bridge to North Fork	151.2-163.2	12.0
15	North Fork of Chena River		56.0
16	East Fork of Chena River		99.2
17	West Fork of Chena River		56.0

[1] Taken from Hallberg 1980.

Appendix Table A3. Summary of population abundance estimates of Arctic grayling ($\geq$ 150 mm FL) in the Chena River, 1968-1988.

Year	Dates	Area[1]	Estimator[2]	Estimate	Confidence[3]
1968	Summer?	2	SN	411/km	393-1,209
	Summer?	6	SN	283/km	228-381
1969	June?	2	SN	596/km	474-850
	June?	6	SN	571/km	439-816
1970	7/2-7/10	2	SN	919/km	690-1,519
	5/26-5/30	6	SN	373/km	346-408
	6/8-7/8	9B	SN	1,005/km	803-1,411
	6/7-7/7	10	SN	1,171/km	876-1,957
1971	8/30-9/3	2A	SN	300/km	192-1,157
	6/2-6/7	2B	SN	1,302/km	958-2,305
	8/30-9/3	2B	SN	2,338/km	1,753-3,897
	6/21-6/24	6	SN	189/km	161-233
1972	6/22-6/26	2A	SN	309/km	236-489
	6/22-6/26	2B	SN	608/km	493-828
	6/19-6/20	6	SN	159/km	124-235
	6/27-6/29	DS	SN	812/km	604-1,393
1973	7/10-7/13	2A	SN	293/km	218-502
	7/3-7/14	2B	SN	424/km	354-545
	7/16-7/17	6	SN	243/km	203-312
	7/18-7/19	DS	SN	500/km	379-806
1974	6/26-6/28	2A	SE	65/km	36-372
	6/25-6/28	2B	SE	488/km	207-1,378
	8/13-8/15	6	SE	100/km	71-164
	7/9-7/11	DS	SE	263/km	221-326
1975	7/10-7/14	6	SE	191/km	114-589
1976	7/19-7/21	2A	SE	258/km	223-307
	7/22-7/24	2B	SE	409/km	323-556
	7/28-7/30	6	SE	163/km	153-175
	8/4-8/6	DS	SE	306/km	285-329
1977	7/5-7/8	2A	SE	318/km	298-343
	7/11-7/14	2B	SE	318/km	280-370
	7/18-7/21	6	SE	173/km	170-177
	7/26-7/30	DS	SE	315/km	283-359
1978	7/14-7/17	2A	SE	69/km	44-156
	7/25-7/28	2B	SE	162/km	148-179
	7/10-7/13	6	SE	226/km	210-243
	8/8-8/11	DS	SE	345/km	333-359

- Continued -

Appendix Table A3. Summary of population abundance estimates of Arctic grayling (≥ 150 mm FL) in the Chena River, 1968-1988 (Continued).

Year	Dates	Area[1]	Estimator[2]	Estimate	Confidence[3]
1979	7/1-7/3	2A	SE	57/km	45-76
	6/26-6/30	2B	SE	201/km	188-216
	8/20-8/23	8A	SE	177/km	161-197
	7/17-7/20	DS	SE	193/km	144-288
1980	7/1-7/4	2B	SE	308/km	229-471
	7/14-7/17	8A	SE	190/km	154-248
	7/29-8/1	DS	SE	236/km	200-287
	8/12-8/15	10B	SE	842/km	640-1,234
1981	8/7-8/10	2B	SN	262/km	223-392
	8/3-8/6	8A	SN	224/km	164-309
	8/11-8/14	DS	SN	302/km	174-440
	7/21-7/24	10B	SN	869/km	466-1,778
1982	7/16-7/20	2B	SN	116/km	79-177
	7/13-7/15	8A	SN	87/km	60-132
	7/23-7/27	DS	SN	232/km	113-579
	7/28-7/30	10B	SN	875/km	529-1563
1983	7/13-7/15	2B	SN	216/km	168-265
	7/5-7/7	8A	SN	119/km	81-545
	7/8,7/11-7/12	DS	SN	209/km	149-303
	7/26-7/28	10B	SN	911/km	647-1,338
	7/19-7/21	12	SN	208/km	138-332
1984	7/16-7/18	2B	SN	211/km	167-268
	7/3,7/5-7/6	8A	SN	139/km	95-215
	7/9-7/11	DS	SN	179/km	124-273
	7/19-7/20	10B	P	493/km	275-1,003
	7/31,8/2-8/3	12	SN	1,318/km	449-6,592
1985	7/10-7/17	2B	SN	189/km	92-287
	6/26-7/2	8A	SN	271/km	189-360
	7/3-7/8	DS	SN	333/km	234-432
	7/22-7/31	10B	SN	1,156/km	304-3,035
	6/12-6/24	12	SN	1,092/km	552-1,643
1986	7/7-8/6	WC	EXP	61,581	SE = 26,987
1987	6/27-7/30	WC	EXP+P	31,502	SE = 3,500
1988	6/26-8/4	WC	EXP+P	22,204	SE = 2,092

[1] Areas are taken from Hallberg (1980); WC = Whole Chena River (lower 152 km).

[2] Estimators are: SN = Schnabel; SE = Schumacher-Eschmeyer; P = Petersen (Ricker 1975); EXP = Expanded estimates (Clark and Ridder 1987a); EXP+P = expanded estimates and a Petersen estimate (Clark and Ridder 1988).

[3] Confidence is either the 95% confidence interval or the Standard Error (SE) of the estimate.

Appendix Table A4. Summary of Arctic grayling creel census on the Chena River, 1955 through 1988.

Year	Dates	Area	Angler hours	Harvest	CPUE	Mean Length
1955	ND	Lower Chena	---	---	0.89	226
1956	ND	Lower Chena	---	---	0.95	251
1957	ND	Lower Chena	---	---	0.62	246
1958	ND	Lower Chena	---	---	0.88	226
1967	4/10 to 8/11	Entire Chena	12,885	---	0.32	245
1968	5/1 to 9/2	Entire Chena	10,269	5,643	0.55	251
1969	7/1 to 9/30	Entire Chena	7,998	7,686	0.96	263
1970	5/1 to 5/30 and 7/1 to 8/31	Entire Chena	12,518	6,770	0.54	---
1972	5/25 to 8/27	Lower Chena	13,116	10,099	0.77	---
1974	7/1 to 8/31	Upper Chena	11,680	18,049	1.72	---
1975	6/1 to 8/31	Upper Chena	22,657	14,067	0.62	252
1976	6/1 to 8/31	Upper Chena	10,762	4,161	0.39	230
1977	6/1 to 8/31	Upper Chena	13,563	9,406	0.71	208
1978	5/29 to 8/31	Upper Chena	10,508	6,898	0.65	222
1979	6/1 to 8/31	Upper Chena	12,564	8,544	0.69	240
1980	5/8 to 9/30	Upper Chena	20,827	16,390	0.78	256
1981	5/1 to 8/31	Upper Chena	15,896	13,549	0.80	---
1982	5/1 to 9/15	Upper Chena	20,379	12,603	0.62	248
1983	5/1 to 9/15	Upper Chena	19,018	10,821	0.58	260
1984	5/6 to 9/15	Upper Chena	17,090	9,623	0.59	278
1985	5/8 to 9/5	Upper Chena	10,613	2,367	0.22	273
1986	5/10 to 9/15	Upper Chena	10,716	3,326	0.31	271
1987	5/18 to 9/15	Upper Chena	9,090	1,260	0.14	290
1988	5/14 to 9/13	Upper Chena	11,763	1,583	0.13	287

Appendix Table A5. Summary of age composition estimates of Arctic grayling in the Chena River stock, 1967-1988.

Year	Age 0 p[1] SE[2]	Age 1 p SE	Age 2 p SE	Age 3 p SE	Age 4 p SE	Age 5 p SE	Age 6 p SE	Age 7 p SE	Age 8 p SE	Age 9 p SE	Age 10 p SE	Age 11 p SE
1967	0.10 0.02	0.13 0.02	0.13 0.02	0.06 0.01	0.17 0.02	0.25 0.02	0.11 0.02	0.05 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1968	0.09 0.03	0.21 0.04	0.24 0.04	0.25 0.04	0.13 0.03	0.03 0.01	0.05 0.02	0.02 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1969	0.00 0.00	0.00 0.00	0.00 0.00	0.22 0.06	0.38 0.07	0.12 0.05	0.16 0.05	0.06 0.03	0.06 0.03	0.00 0.00	0.00 0.00	0.00 0.00
1973	0.00 0.00	0.06 0.02	0.13 0.02	0.61 0.03	0.18 0.03	0.03 0.01	0.00 0.00	0.01 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1974	0.00 0.00	0.04 0.01	0.11 0.02	0.12 0.02	0.44 0.03	0.25 0.02	0.04 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1975	0.00 0.00	0.00 0.00	0.13 0.04	0.25 0.05	0.13 0.04	0.26 0.05	0.19 0.04	0.02 0.02	0.01 0.01	0.00 0.00	0.00 0.00	0.00 0.00
1976	0.00 0.00	0.10 0.02	0.24 0.03	0.29 0.03	0.15 0.02	0.09 0.02	0.11 0.02	0.02 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1977	0.00 0.00	0.06 0.02	0.34 0.03	0.45 0.03	0.08 0.02	0.06 0.02	0.02 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1978	0.00 0.00	0.15 0.02	0.38 0.03	0.22 0.03	0.21 0.02	0.03 0.01	0.01 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1979	0.00 0.00	0.11 0.02	0.20 0.03	0.45 0.03	0.17 0.03	0.05 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1980	0.00 0.00	0.02 0.01	0.12 0.02	0.39 0.03	0.28 0.03	0.13 0.02	0.05 0.01	0.01 0.01	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1981	0.00 0.00	0.16 0.02	0.13 0.02	0.40 0.02	0.12 0.02	0.12 0.02	0.06 0.01	0.01 0.01	0.01 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1982	0.00 0.00	0.06 0.01	0.30 0.03	0.11 0.02	0.35 0.03	0.09 0.02	0.04 0.01	0.02 0.01	0.02 0.01	0.00 0.00	0.00 0.00	0.00 0.00
1983	0.01 0.01	0.07 0.01	0.11 0.01	0.45 0.02	0.08 0.01	0.17 0.02	0.06 0.01	0.03 0.01	0.01 0.01	0.00 0.00	0.00 0.00	0.00 0.00
1984	0.00 0.00	0.19 0.02	0.07 0.01	0.12 0.02	0.41 0.02	0.08 0.01	0.09 0.01	0.02 0.01	0.01 0.01	0.00 0.00	0.00 0.00	0.00 0.00
1985	0.00 0.00	0.02 0.00	0.16 0.01	0.11 0.01	0.14 0.01	0.32 0.01	0.10 0.01	0.10 0.01	0.04 0.00	0.02 0.00	0.00 0.00	0.00 0.00
1986	0.00 0.00	0.00 0.00	0.00 0.00	0.65 0.01	0.07 0.01	0.09 0.01	0.13 0.01	0.04 0.01	0.02 0.00	0.00 0.00	0.00 0.00	0.00 0.00
1987	0.00 0.00	0.00 0.00	0.05 0.01	0.08 0.01	0.60 0.03	0.07 0.01	0.05 0.01	0.10 0.02	0.02 0.01	0.02 0.00	0.00 0.00	0.00 0.00
1988	0.00 0.00	0.00 0.00	0.09 0.02	0.15 0.02	0.12 0.02	0.42 0.04	0.07 0.01	0.06 0.01	0.07 0.01	0.02 0.00	0.00 0.00	0.00 0.00

[1] p = the proportion of the sample at age.
[2] SE = the standard error of p.

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Appendix Table A6. Summary of mean length at age estimates of Arctic grayling from the Chena River, 1967-1988.

Year	Age 0 n[1] FL[2]		Age 1 n FL		Age 2 n FL		Age 3 n FL		Age 4 n FL		Age 5 n FL		Age 6 n FL		Age 7 n FL		Age 8 n FL		Age 9 n FL		Age 10 n FL		Age 11 n FL	
1967	30	25	41	135	41	186	17	243	51	272	77	293	32	321	15	335	0	---	0	---	0	---	0	---
1968	10	73	24	103	28	150	29	214	15	255	3	289	6	304	2	372	0	---	0	---	0	---	0	---
1969	0	---	0	---	0	---	11	191	19	236	6	273	8	304	3	317	3	356	0	---	0	---	0	---
1973	0	---	11	111	25	167	121	194	36	215	6	279	0	---	1	310	0	---	0	---	0	---	0	---
1974	0	---	12	130	32	169	37	199	133	217	76	236	12	259	1	315	0	---	0	---	0	---	0	---
1975	0	---	0	---	12	171	22	200	12	229	23	238	17	258	2	275	1	320	0	---	0	---	0	---
1976	0	---	26	144	61	175	74	194	39	221	24	249	28	270	4	308	0	---	0	---	0	---	0	---
1977	0	---	14	112	77	176	102	208	19	245	13	263	4	299	0	---	0	---	0	---	0	---	0	---
1978	0	---	39	128	102	167	59	206	56	230	9	256	2	290	1	325	0	---	0	---	0	---	0	---
1979	0	---	25	107	44	165	99	197	38	236	11	266	1	310	0	---	0	---	0	---	0	---	0	---
1980	0	---	4	114	31	154	97	198	71	231	33	259	12	292	3	327	0	---	0	---	0	---	0	---
1981	0	---	61	112	48	162	152	187	46	215	47	240	22	268	5	287	3	310	0	---	0	---	0	---
1982	0	---	19	105	88	137	34	190	105	215	26	251	11	279	7	305	6	337	0	---	0	---	0	---
1983	6	62	33	114	53	151	215	177	38	216	83	239	29	273	13	307	7	338	0	---	0	---	0	---
1984	0	---	82	97	32	153	54	182	179	213	36	226	40	257	7	275	6	321	0	---	0	---	0	---
1985	0	---	42	108	300	141	203	188	267	215	609	233	182	285	188	285	80	308	30	377	2	377	0	---
1986	0	---	40	109	104	164	755	184	79	220	110	251	153	270	42	301	22	318	5	330	1	346	0	---
1987	0	---	0	---	54	160	92	204	691	228	115	274	76	292	184	309	30	324	31	338	2	353	0	---
1988	0	---	7	108	135	172	238	216	181	239	707	260	118	288	95	313	110	325	35	347	7	337	2	374
Average		40		113		157		190		224		245		271		299		316		334		361		374

[1] n = sample size.
[2] FL = the arithmetic mean fork length in millimeters.

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Appendix Table A7. Summary of Relative Stock Density (RSD) indices of Arctic grayling ($\geq$ 150 mm FL) captured by electrofishing from the Chena River, 1972-1988.

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
1972 (2A, 2B, 6, DS) - 6/19-6/22[2]					
Sample size	1,392	42	3	0	0
RSD	0.969	0.029	0.002	0.000	0.000
Standard Error	0.005	0.004	0.001	0.000	0.000
1973 (2A, 2B, 6, DS) - 7/3-7/19					
Sample size	176	7	0	0	0
RSD	0.962	0.038	0.000	0.000	0.000
Standard Error	0.014	0.014	0.000	0.000	0.000
1974 (2A, 2B, 6, DS) - 6/25-8/15					
Sample size	889	58	0	0	0
RSD	0.939	0.061	0.000	0.000	0.000
Standard Error	0.008	0.008	0.000	0.000	0.000
1975 (6) - 7/10-7/14					
Sample size	76	13	0	0	0
RSD	0.854	0.146	0.000	0.000	0.000
Standard Error	0.038	0.038	0.000	0.000	0.000
1976 (2A, 2B, 6, DS) - 7/19-8/6					
Sample size	613	59	1	0	0
RSD	0.911	0.088	0.002	0.000	0.000
Standard Error	0.011	0.011	0.001	0.000	0.000
1977 (2A, 2B, 6, DS) - 7/5-7/30					
Sample size	916	30	0	0	0
RSD	0.969	0.031	0.000	0.000	0.000
Standard Error	0.006	0.006	0.000	0.000	0.000
1978 (2A, 2B, 6, DS) - 7/10-8/11					
Sample size	841	20	0	0	0
RSD	0.976	0.024	0.000	0.000	0.000
Standard Error	0.005	0.005	0.000	0.000	0.000

- Continued -

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Appendix Table A7.   Summary of Relative Stock Density (RSD) indices of Arctic grayling (≥ 150 mm FL) captured by electrofishing from the Chena River, 1972-1988 (Continued).

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
1979 (2A, 2B, 8A, DS) - 6/26-8/23					
Sample size	802	13	0	0	0
RSD	0.984	0.016	0.000	0.000	0.000
Standard Error	0.004	0.004	0.000	0.000	0.000
1980 (2B, 8A, DS, 10B) - 7/1-8/15					
Sample size	1,260	53	2	0	0
RSD	0.958	0.040	0.001	0.000	0.000
Standard Error	0.006	0.005	0.001	0.000	0.000
1981 (2B, 8A, DS, 10B) - 7/21-8/14					
Sample size	1,247	42	1	0	0
RSD	0.966	0.033	0.001	0.000	0.000
Standard Error	0.005	0.005	0.001	0.000	0.000
1982 (2B, 8A, DS, 10B) - 7/13-7/30					
Sample size	919	76	5	0	0
RSD	0.919	0.076	0.005	0.000	0.000
Standard Error	0.009	0.008	0.002	0.000	0.000
1983 (2B, 8A, DS, 10B, 12) - 7/5-7/28					
Sample size	1,560	152	10	0	0
RSD	0.906	0.088	0.006	0.000	0.000
Standard Error	0.007	0.007	0.002	0.000	0.000
1984 (2B, 8A, DS, 10B, 12) - 7/3-8/3					
Sample size	1,349	74	4	0	0
RSD	0.945	0.052	0.003	0.000	0.000
Standard Error	0.006	0.006	0.001	0.000	0.000
1985 (2B, 8A, DS, 10B, 12) - 6/12-7/31					
Sample size[3]	ND	ND	ND	ND	ND
RSD	---	---	---	---	---
Standard Error	---	---	---	---	---

- Continued -

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Appendix Table A7.   Summary of Relative Stock Density (RSD) indices of Arctic
grayling ($\geq$ 150 mm FL) captured by electrofishing from the
Chena River, 1972-1988 (Continued).

	RSD Category[1]				
	Stock	Quality	Preferred	Memorable	Trophy
1986 (lower 152 km) - 7/7-8/6					
Sample size	1,268	160	29	0	0
RSD	0.870	0.110	0.020	0.000	0.000
Standard Error	0.009	0.008	0.004	0.000	0.000
1987 (lower 152 km) - 6/27-7/30					
Sample size	1,678	693	154	0	0
RSD	0.665	0.274	0.060	0.000	0.000
Adjusted RSD[4]	0.779	0.188	0.032	0.000	0.000
Standard Error[5]	0.036	0.035	0.006	0.000	0.000
1988 (lower 152 km) - 6/26-8/4					
Sample size[6]	1,855	1,242	217	0	0
RSD	0.627	0.319	0.054	0.000	0.000
Standard Error	0.043	0.034	0.005	0.000	0.000

[1] Minimum lengths for RSD categories are (Gablehouse 1984):
     Stock - 150 mm FL; Quality - 270 mm FL; Preferred - 340 mm FL;
     Memorable - 450 mm FL; and, Trophy - 560 mm FL.
[2] Year (sections sampled (taken from Hallberg 1980)) - sampling dates.
[3] Lengths were taken in 1985, but not reported in Holmes et al. (1986).
[4] RSD was adjusted to correct for bias due to the electrofishing boat (Clark
     and Ridder 1988).
[5] Standard error is for adjusted RSD only.
[6] Sample sizes do not correspond to RSD proportions because RSD proportions
     are weighted by abundance estimates in a stratified design.

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